*Volume 6*

# LUBRICATION

*Number 5*

*A TECHNICAL PUBLICATION*
*DEVOTED TO THE SELECTION*
*AND USE OF LUBRICANTS*

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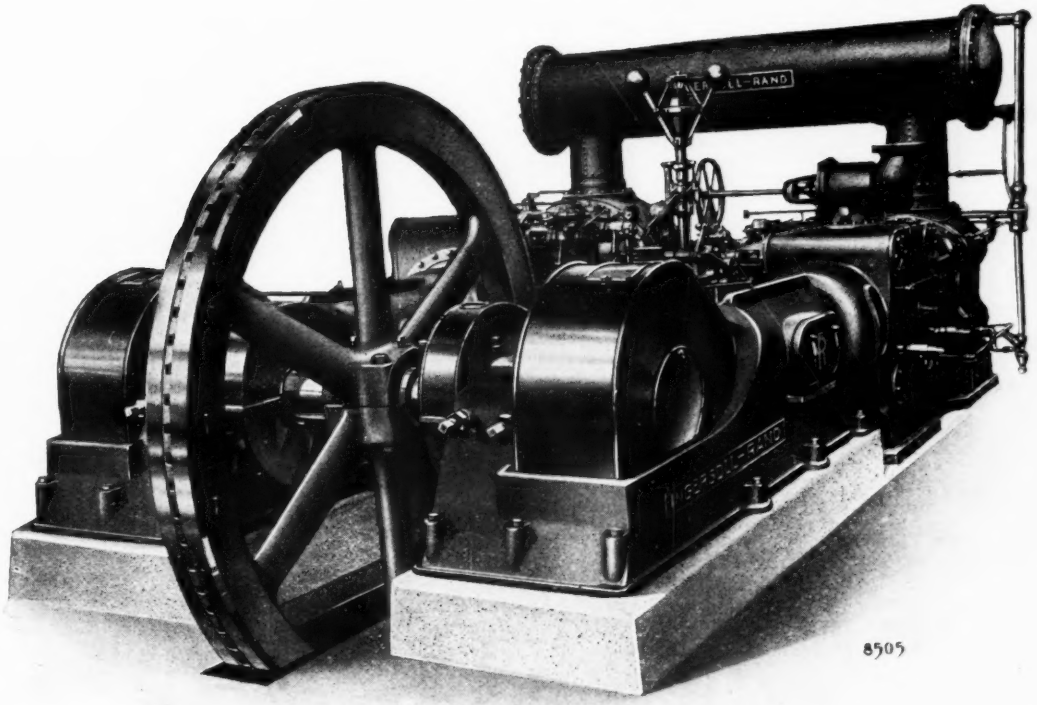



## COMPRESSED AIR MACHINERY
## Its Lubrication

THE rapidly increasing application and many advantages of compressed air have led to the development of a particular class of machinery capable of obtaining the greatest efficiency and economy from this form of power. Compressed air is clean, odorless and easy to control and manipulate. It is safe when used under proper conditions and may be conveniently stored and economically transported over moderate distances. Because there is no fire risk entailed in its use, it is an ideal power for mine use, and in railroad and sub-aqueous engineering it is in-

dispensable. To obtain the greatest efficiency in these operations many refinements in the design and construction of compressed-air machines have been made, but probably no factor has a more important bearing upon their operation than lubrication which, if unsuitable, may offset all the advantages of the perfected machinery.

Before taking up the question of lubrication, however, let us consider the compression system in detail. This system consists primarily of a compressor, coolers, storage tanks, transmission lines and expansion tools or apparatus, which latter may also be supplied with preheaters. The function of the air compressor is to furnish air at such a pressure that it is capable of exerting a force on expansion apparatus, thereby performing useful work. In order to get air into this condition work must be done upon it. This reduces the volume, increases the pressure, and, unless it is continually cooled, causes the air to get very hot. If air drawn into a compressor at a temperature of 60 degrees F. were to be compressed to 100 lbs. gauge pressure and no heat allowed to escape, the temperature would rise to 485 degrees F. If this heat could be retained in the air during storage and transmission, its energy could be converted into useful work, but as the air soon cools to atmospheric temperature, it is advantageous to have this cooling take place as soon as practical and if possible in the compressor, as then the back pressure is reduced and less work required to produce the required degree of compression.

By cooling the walls of the compression chamber considerable heat may be removed from the air, but not as completely as desired, as there is insufficient time for the air to give up all its heat. While it is advantageous to cool all the walls it is not generally considered practical to cool the moving parts, and only the stationary parts are arranged for cooling. Some attempts have been made to spray water into the air during compression but this expedient generally introduces more complications than are warranted by the results obtained and is rarely used. Small compressors, such as are found in garages, are usually only air cooled, but the majority of air compressors are cooled by means of water jackets.

An ideal air compressor would have no clearance space at the end of the compression stroke or cycle, as any air remaining in the clearance space simply expands again, reducing the capacity of the unit. As zero clearance is practically impossible as well as inexpedient, and cooling in the compression chamber limited, when high pressures are desired it is found advantageous to use multiple-stage units, cooling the air between the stages in what are known as intercoolers.

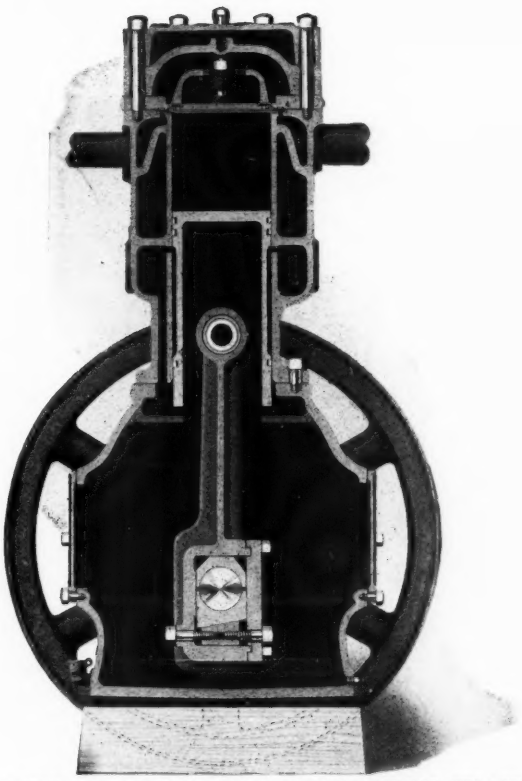
The utilization of compressed air as a motive power is the reverse of the above. As the air under pressure tends to expand it can be made to do useful work by admitting it to apparatus equipped with pistons or turbines. In the process of compression, air becomes heated, but in expanding it becomes cold and may reach so low a temperature as to cause snow to collect around the exhaust ports. This snow may be caused by moisture in the operating air or by the external atmosphere coming in contact with the chilled apparatus.

The difficulties in the way of providing proper lubrication for compressed-air machinery are largely due to the extreme high and low temperatures to which the lubricant is exposed, and, in the case of the compressor, to the fact that oil when in contact with heated air may deteriorate and become a source of trouble unless proper precautions are taken. The lubrication of compression and expansion machinery presents radically different problems and these shall be considered independently.

Air compressors as built today may be grouped under the following heads:—

(a) Blowers.
(b) Rotary compressors.
(c) Blowing engines.
(d) Single-stage reciprocating compressors.
(e) Multiple-stage or compound reciprocating compressors.

Blowers may be of the centrifugal fan or rotary type and are adapted to supplying



VERTICAL SINGLE-STAGE, SINGLE-ACTING, SPLASH-LUBRICATED AIR COMPRESSOR. BUILT BY THE GARDNER GOVERNOR COMPANY

large quantities of air at low pressures. Centrifugal fans consist of a more or less scientifically designed "paddle-wheel," revolving in an eccentric casing. These operate at pressures below one pound and are much used in heating and ventilating. Blowers of the bucket type combine with the centrifugal action a pressure action due to the shape of the bucket or blade and may impart a velocity to the air in excess of the peripheral speed of the rotor.

Rotary compressors differ widely in design but as a rule use either sliding vanes rotating in an eccentric housing or rotating gears or cams so arranged as to alternately increase and decrease the enclosed air space. This type has not attained such general application as the piston type, both because of the complexity of the moving parts and its inability, as a general rule, to produce large volumes and high pressures as easily as the piston compressor. In certain specific cases, however, the rotary compressor is quite efficient and the opportunity for future development is great.

Blowing engines are very large, slow-moving, reciprocating compressors, which are employed principally in steel plants for supplying large quantities of comparatively low pressure air to the blast furnaces. These may be either of the horizontal or vertical type and present no unusual lubricating difficulties.

The reciprocating-piston type of compressor is by far the most important and is used more widely than any other. These may be either single-stage where low pressures and large volumes are desired, or multiple-stage where high pressures are required.

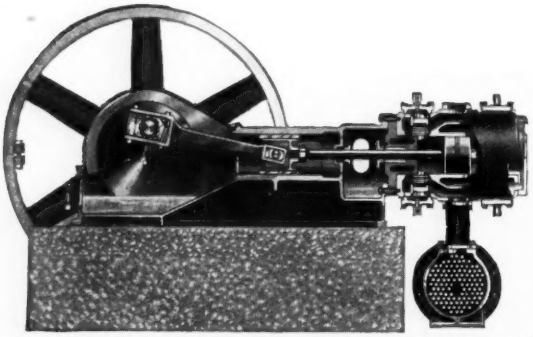
Single-stage compressors are built both single and double acting and may be either horizontal or vertical. Most vertical single-stage compressors are of the one-cylinder, single-acting variety. The piston in these machines is usually of the double-trunk type, the upper section of the piston carrying several rings which seal the cylinder and prevent excess oil from being drawn in. The lower portion of the piston usually carries one ring only. Vertical single-stage compressors are built in various sizes from one cubic foot capacity upward. Practically all horizontal single-stage compressors are of the one-cylinder, double-acting type.

Multiple-stage reciprocating compressors are used when high pressures are desired. In this type of compressor the air receives an initial compression in one cylinder. Passing through an intercooler, it is compressed in a second cylinder and so on until the desired compression is accomplished. Because of efficiency in cooling and because clearance losses are reduced, multiple-stage compressors are the most efficient. Theoretically the more stages the higher the efficiency, but the size and cost of machinery and also frictional losses limit the number of stages to four at the most.

Intercoolers placed between the stages, and aftercoolers placed after the high-pressure stage may be simply water-jacketed tanks or they may contain coils through which cold water circulates. Some intercoolers and aftercoolers contain a large number of straight

tubes and are built similar to a steam condenser. Not only is the air cooled by coming in contact with the cold coils but water and oil are precipitated from it as well. Aftercoolers are frequently built into the receiving tank. In cases where air is breathed under pressure as in tunnels, etc., cooling is very essential.

The receiving tank should be strong, airtight and clean, and cannot be too large. The discharge from a compressor is more or less pulsating in character and a large receiving tank will absorb these pulsations and deliver a steady flow to the pipe lines. Due to the condensation of the moisture and oil vapor in the air, water and oil accumulate in the storage tank and sometimes in the aftercooler. Some means should always be provided for drawing these off.



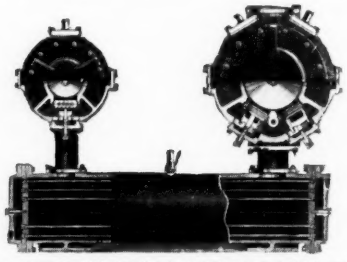
WORTHINGTON HORIZONTAL, BELT-DRIVEN, TWO-STAGE AIR COMPRESSOR. EXTERNAL BEARINGS, SPLASH LUBRICATED

The lubrication of blowers presents no particular difficulties and depends upon the type of bearing or its accessibility. A good grade of light machine oil or a high-grade grease are usually found satisfactory.

Rotary compressors usually require only a good grade of light machine oil of sufficient body to maintain a satisfactory seal between the moving parts and the housing. Where high pressures are attained the same conditions exist as in high-pressure piston compressors and will be considered under that head. Rotary compressors are often used with other gases than air and require an oil which will not be affected by these gases. These special cases should be discussed with the lubrication engineer of a reputable company and will not be considered at this time.

In blowing engines the pressures and temperatures are low and the lubrication of the cylinders may not require a special type of oil, but it is the best policy to use an oil suitable for the high-pressure type of piston compressor.

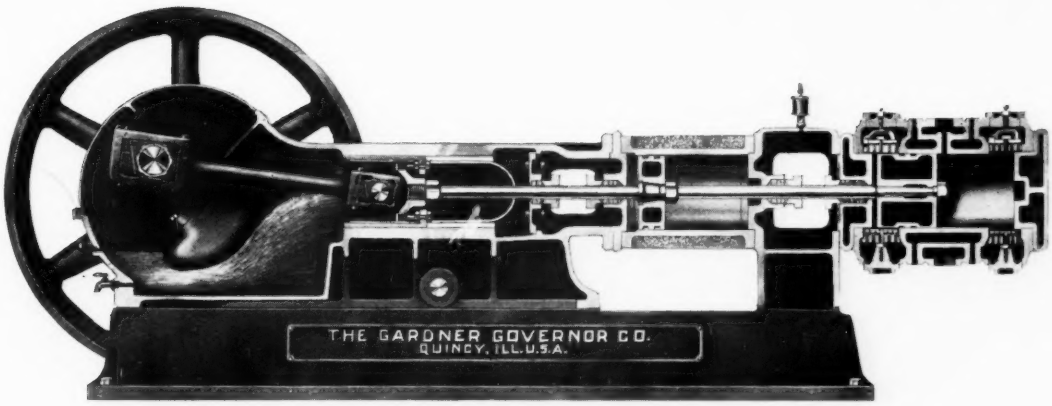
The lubrication of the external bearings, crossheads and cranks of piston compressors is no different from that of similar classes of steam machinery, the oil being of proper character to withstand the pressures and the tendency toward gumming and deterioration. When, however, as in the case of many vertical and some horizontal units the splash system is used to lubricate the cylinder, the characteristics of the oil are governed by the requisites of piston lubrication. If properly designed so as to get the right amount of oil to the various points, and in particular neither too much nor too little oil to the cylinder walls, the splash system is ideal as it



THIS AND THE ILLUSTRATION ON THE LEFT SHOW THE ARRANGEMENT OF THE INTERCOOLER. NOTE RELATIVE SIZES OF THE CYLINDERS

requires no attention except the filling of the crank case when necessary. These factors should be considered carefully when this system is contemplated.

In selecting an oil for the internal lubrication of the air compressor the position and condition of the cylinder, the speed of operation and the weight and fit of the piston must always be considered. Other factors which govern are the degree of compression employed, the temperature developed, the methods used in cooling the cylinder and the manner of applying the oil. In vertical compressors practically the only pressure on the cylinder walls is that due to the tension of the piston rings, and an oil of sufficient body to maintain a seal about the rings will be found quite adequate to prevent frictional wear. In horizontal

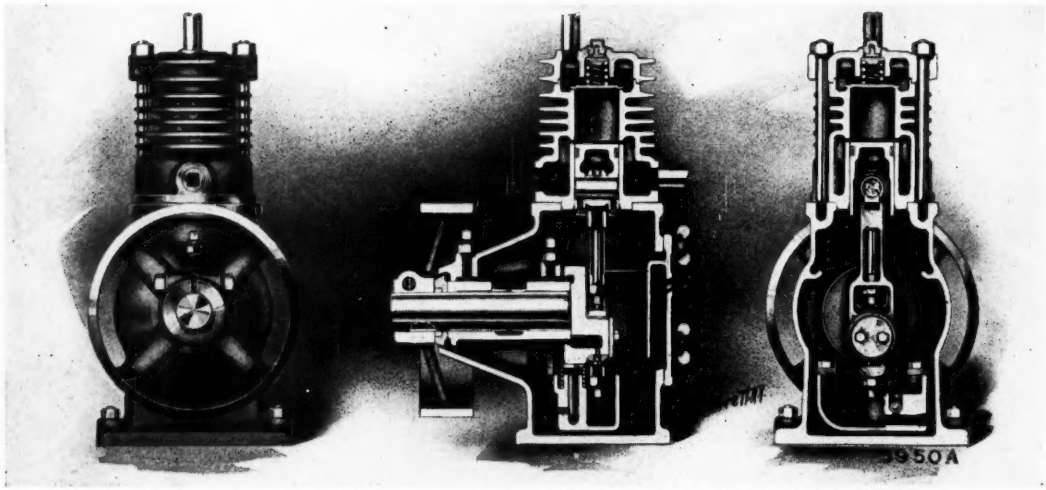



A STRAIGHT-LINE, STEAM-DRIVEN, SINGLE-STAGE AIR COMPRESSOR. EXTERNAL BEARINGS SPLASH LUBRICATED

compressors the weight of the piston is carried by the bottom of the cylinder and it is necessary, as a result, to use an oil of sufficient body to prevent metal contact even in the presence of considerable heat. Low-speed compressors and those having heavy or loose-fitting pistons require a heavier oil than those operating at high speeds or those fitted with light or tight-fitting pistons. When pressures and temperatures are high, heavy-viscosity oils must be used as high temperatures reduce the viscosity and allow air to slip back past the piston. For lower pressures and temperatures, lighter grades prove quite successful. It should be accepted as a definite rule that the lowest viscosity oil that will successfully lubricate the cylinder wall and seal the piston rings and valves should be used in the air compressor.

There is some controversy among engineers over the relative merits of low and high flash oils. As usually manufactured, no straight-run oil which has sufficient viscosity to take care of the friction of the piston, has a flash point under 300 degrees F. at atmospheric pressure. To get a flash at this temperature a flame or spark must be applied. Spontaneous ignition will not take place even under a very much higher temperature. In both these cases there must be a critical mixture of vapor and air, the proportions of which have narrow limits. If the compressor is properly operated the excess of air over oil is so great that it is practically impossible to get an explosive mixture even if a spark were present.

While the parallelism is not strictly perfect, high-flash oils also have high viscosities and what is more to the point, high distillation end points. The cylinder walls are cooled by water jacketing and hence the temperature of the oil layer next to the wall is practically little above that of the wall. The oil layer exposed to the heated air, however, becomes much hotter than the rest of the oil body and a portion of it will vaporize. As oils are composite mixtures, different portions distilling at different temperatures, the lighter products will distill, leaving the heavy ends dissolved in the oil next to the wall. The final result is the building up of a gummy mass which has such a low vapor pressure and high distillation point that it is not taken up by the air as fast as is necessary. Oil when subjected to heat, especially hot air, gradually decomposes into volatile compounds and carbon. The extent of this decomposition depends on the temperature and length of time the oil is exposed to the heat. This vaporization and the breaking down of the oil are going on simultaneously and if the distillation is slow or the quantity large the oil is subjected to breaking down conditions during a longer period and more carbon is formed. Compounded oils are also contributory to the formation of carbon. The fixed oils and fats used for compounding do not distill when exposed to high temperatures. Instead they decompose and form a gummy and particularly objectionable form of carbon which adheres to the valves and discharge passages.




GARAGE TYPE OF AIR COMPRESSOR. THIS COMPRESSOR IS BELT-DRIVEN AND SPLASH LUBRICATED

Carbon may be formed in cylinders in a hard mass or it may be produced in the shape of dust and pass out with the air. In the latter case it will probably collect at elbows or on sharp edges and become mixed with dirt taken in by the air and oil vaporized in the cylinder and condensed at these points. If formed in the cylinder, carbon being a poor conductor, may become heated considerably above the temperature of the cylinder walls. Whether carbon can become sufficiently heated to ignite or not is still a disputed question. Some claim incandescent carbon to be the cause of explosions, but that is doubtful for, as we have said previously, to have an explosion there must be a critical mixture of oil and air. Hard carbon, however, is always a nuisance and many times it accumulates on the valves and valve seats and is packed firmly into the ends of the cylinders, causing the valves to leak and frequently resulting in the cutting of the valves and scoring of the cylinders. Cases have been found where carbon collected in the valve passages and bends of piping to such an extent as to restrict the opening through which the compressed air had to pass. When once started this carbon continues to build up and so narrows the passage that enormous pressures may be produced and eventually cause an explosion back of the obstruction.

It is claimed that carbon may be successfully cleaned from air systems with soap suds. The mixture, containing one part of laundry, or preferably soft soap, to 12 to 15 parts of water, may be fed into the cylinder through the lubricating system, instead of oil, for several hours. Feed the suds liberally and then blow the mixture of carbon, oil and water out of the system. Some engineers recommend this treatment weekly, but if correct lubrication is employed cleaning will have to be resorted to only after long periods of operation, if at all. Kerosene or gasoline, should, under no circumstances, be used for purging the cylinder, and when soap suds are used, oil always should be fed to the cylinder for an hour or so before the compressor is shut down. This is to prevent rusting. Regularity in cleaning and blowing out the discharge lines and receivers will greatly diminsh the possibility of an explosion, but the best insurance is correct lubrication.

The problem, then, which confronts the lubrication engineer is the production of an oil which will not form hard adhering carbon, and still have a sufficiently high viscosity to act as a good lubricant. To meet these conditions and produce an oil with a fairly low distillation end point, it has been found advisable to prepare an oil especially for the purpose and not use any of the ordinary grades found in general machine practice. This oil should be a straight-run, filtered, pure mineral product flashing above 300 degrees F. and giving a low carbon residue on

distillation. The viscosity will depend on the type of compressor and the general operating conditions.

The Compressed Air Society has issued the following specifications:—

## Paraffine Base Oils

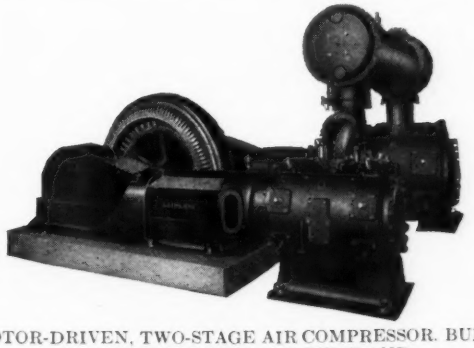
| | Minimum | Average | Maximum |
|---|---|---|---|
| Gravity, Beaume | 28-32 deg. | 25-30 deg. | 25-27 deg. |
| Flash point, open cup | 375-400 deg. F. | 400-425 deg. F. | 425-500 deg. F. |
| Fire | 425-450 deg. F. | 450-475 deg. F | 475-575 deg. F. |
| Viscosity (Saybolt) at 100 deg F. | 120-180 sec. | 230-315 sec. | to 1500 sec. |
| Color | Yellowish | Reddish | Dark Red to Green |
| Congealing point (pour test) | 20-25 deg. F. | 30 deg F. | 35-45 deg. F. |

## Asphalt Base Oils

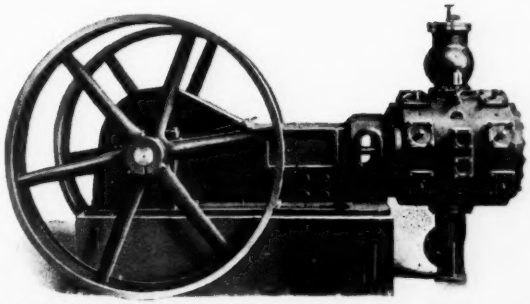
| | Minimum | Average | Maximum |
|---|---|---|---|
| Gravity, Beaume | 20-22 deg. | 19.8-21 deg. | 19.5-20.5 deg. |
| Flash point, open cup | 305-325 deg. F. | 315-335 deg. F. | 330-375 deg. F. |
| Fire | 360-380 deg. F. | 370-400 deg. F. | 385-440 deg. F. |
| Viscosity (Saybolt) at 100 deg. F. | 175-225 sec. | 275-325 sec. | 475-750 sec. |
| Congealing point (pour test) | 0 deg. F. | 0 deg. F. | 0 deg. F. |

These specifications are general and cover a broad range. Our principal criticism is that they are too general and too broad. If followed strictly almost any machine oil on the market would satisfy these specifications. This is not the fault of the people who drew them up but is due to the fact that what is and what is not a good air compressor oil can be learned only after much experiment with different oils to learn their behaviour under the conditions found in the compression chamber.

The methods adopted for feeding oil to the air compressor cylinders vary in different types and makes of machines. Ordinarily, however, the oil is introduced into the air intake at the point where it enters the valve chest. Here it is atomized by the inrushing



MOTOR-DRIVEN, TWO-STAGE AIR COMPRESSOR. BUILT BY THE WORTHINGTON PUMP AND MACHINERY CORPORATION



A HORIZONTAL, SINGLE-STAGE, DOUBLE-ACTING AIR COMPRESSOR. BUILT BY THE WORTHINGTON PUMP AND MACHINERY CORPORATION

air and carried to the valves and all parts of the cylinder as in the steam engine. As in steam cylinder lubrication atomization is improved by introducing the oil some distance from the valve, but as the amount of oil supplied is very small the point of introduction is never located very far from the valve chest. The oil may be fed to the cylinder by means of vacuum cups, but greater economy and satisfaction will be obtained through the use of automatic force-feed lubricators. Force-feed lubricators are not affected by changes in the air pressure and feed the oil in exact conformity with the speed of operation. In order to prevent oil accumulating in the cylinder, lubricators should be shut off just as the compressor is stopped.

We shall not attempt to lay down any fixed rule as to the amount of oil that should be supplied to the air compressor cylinder. This will depend upon the size of the compressor, its speed, and the condition of the piston and cylinder walls. It has been our experience, however, that more trouble is caused by using too much oil than too little. Just enough oil should be used to prevent frictional wear and permit the free and easy operation of all parts. More may lead to trouble. If upon removal, the discharge valve is greasy, enough oil is being fed to the cylinder. If it is dry, feed a little more. We know of numerous cases where compressors are being efficiently lubricated with two and three drops of oil per minute and it has been claimed as a rough rule that one or two drops of oil should be used for every 500 square feet of cylinder surface swept by the pistons per minute, the quantity depending upon the

degree of compression and the conditions in the cylinder.

While we have attempted to give a general idea of the characteristics necessary to a high-class compressor oil and some brief notes on its application, the number of types of compressors is so great and the requirements of the various types so diverse that it is practically impossible to give more than a general idea. Unless thoroughly advised by the manufacturer, it is advisable at the least sign of trouble to consult the engineer of a reputable oil company, who has made a study of the subject.

**At some later date we shall publish in LUBRICATION an article on the Lubrication of Pneumatic Machinery**

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# Cement Mill Lubrication

CONTINUED FROM MAY

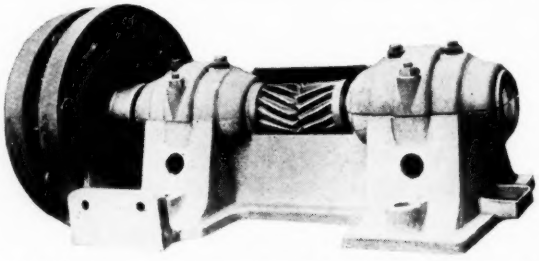
In the May issue of Lubrication we described the lubricating problems presented by the crushing and drying machinery employed in the cement mill. We are now ready to discuss the lubrication of those machines which are employed in finally preparing the dry raw materials for the kilns.

The simplest of these is the ball mill.

A ball mill is essentially a revolving steel drum partially filled with steel balls which continually roll to the bottom of the drum grinding the particles of rock between them and beneath them. The tube mill mentioned in the next paragraph is very similar to the ball mill. It is larger, however, and is designed for finer grinding. A device which combines both the ball and tube mill in one cylinder is called a "compeb" mill by the makers.

Those ball mills which are carried upon horizontal shafts are difficult to lubricate because of the great weight carried by the shaft and the fine grit which gets into the bearings. Every possible precaution is taken to keep dust out of the bearings, but it always seems to get in somehow and is frequently the cause of their rapid destruction. The main shaft bearings are always made large so that the unit loads are not excessive, but in spite of this it is necessary to use a lubricant possessing considerable body in order to prevent undue frictional heat. Fortunately, ball mills revolve slowly and there is no objection to a heavy lubricant from the standpoint of speed. Cup grease is the most suitable lubricant for these bearings.

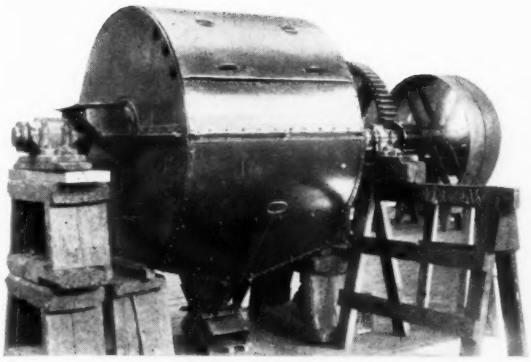
Bearings may run hot because an unsuitable lubricant is used, because they receive an insufficient amount of or no lubricant, or because of some mechanical fault such as poor alignment of the shaft, insufficient clearance, etc. In any case as soon as the heating is discovered the machine should be stopped. This is not always possible in the cement mill, and as pouring water over the bearing is neither desirable nor of permanent benefit, the most



PINION SHAFT FOR EITHER A BALL OR TUBE MILL. IN THIS CASE EQUIPPED FOR DIRECT MOTOR CONNECTION

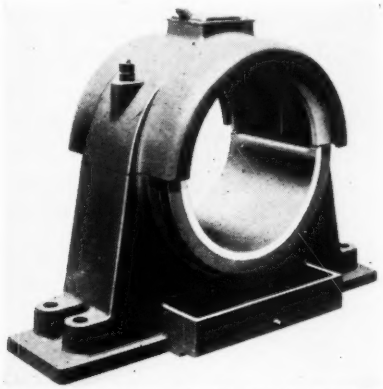
efficacious way of reducing the heat is to loosen up the bearing and then flood it with cylinder oil. At the first opportunity the bearing should be examined to see that the grooves and oil feeds are not clogged with molten babbitt, and all mechanical faults corrected. If the bearing then continues to heat the chances are that lubrication is at fault and the lubricating engineer should be called in at once.

Because of the speed at which it revolves

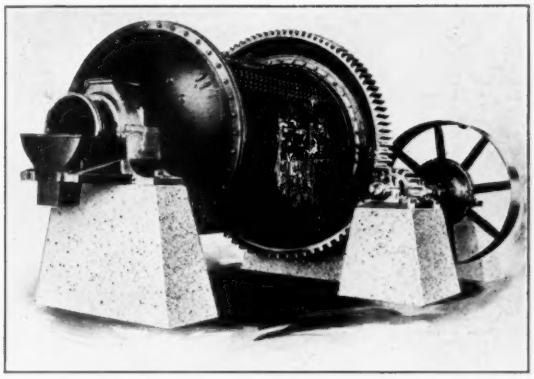


A BALL MILL CARRIED UPON ORDINARY BEARINGS. BUILT BY THE ALLIS-CHALMERS COMPANY

the pinion shaft of the ball mill is usually carried in ring-oiled bearings. The most suitable lubricant for these is an engine or machine oil of medium viscosity, care being taken to clean out the reservoirs frequently and to add fresh oil to make up for that lost. Most trouble starts in ring-oiled bearings through the reservoirs being too small to allow the oil to cool properly. When the bearings heat, the chances are that an oil having an unnecessarily high viscosity will be installed but this only aggravates the trouble. It is possible to increase the capacity of some reservoirs by tapping a short length of pipe into the lower part and plugging its lower end. The most satisfactory lubricant for the gears of the ball mill is one with sufficient body to prevent metallic contact under heavy loads and capable of resisting the drying action of the dust.



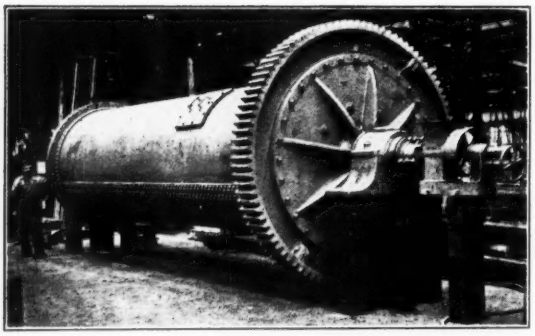
A TRUNNION BEARING. NOTE THAT BOTTOM HALF ONLY IS LINED. UPPER HALF MAY BE PACKED WITH WASTE



A BALL MILL CARRIED UPON TRUNNION BEARINGS BUILT BY THE POWER AND MINING MACHINERY COMPANY

Some ball mills, tube mills, and the compeb mill are carried upon trunnion bearings. These bearings undoubtedly present the most difficult lubricating problem of the whole cement mill. The difficulty may be attributed to three causes. In the first place the load upon the bearings is very large. Second; the trunnions often become heated by having hot pulverized material pass through them, and third; considerable dust and grit find their way between the bearing surfaces. The one remedy for all of these troubles is a grease or oil possessing great body and a high liquefying point, although the temperature of the bearings can always be reduced by making provision for cooling water circulation. The trunnion bearings are very large and, as all the thrust is due to the weight of the mill and its contents, are commonly lined upon the bottom only, this lining being readily replaced when worn. The caps of the bearings are not lined and merely serve as dust shields and receptacles for the waste and grease used in their lubrication. The trunnion bearings run satisfactorily when packed with a high-grade yarn grease, but lubrication may frequently be improved by adding a little black oil to the grease at frequent intervals. The same conditions govern the lubrication of the gears of these mills as those described for the ball mill above. The same may be said about the pinion shaft bearings.

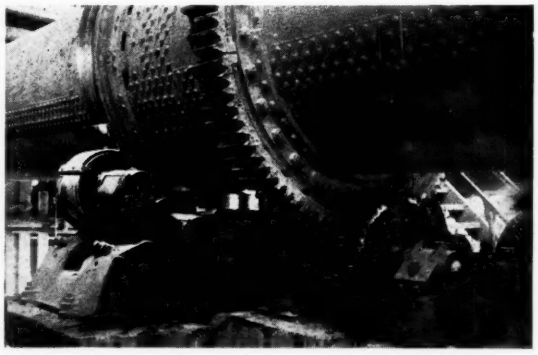
A machine frequently employed for preparing the raw materials for the kilns is the Fuller-Lehigh mill. The accompanying il-



A LARGE TUBE MILL FITTED WITH TRUNNION BEARINGS. BUILT BY THE POWER AND MINING MACHINERY COMPANY

lustration shows one of these mills and will convey some idea of how it operates. The balls, four in number, are pushed around the internal circumference of a wearing ring or die about 160 times per minute and are consequently pressed against the die with great force. The rock is ground between the balls and the die.

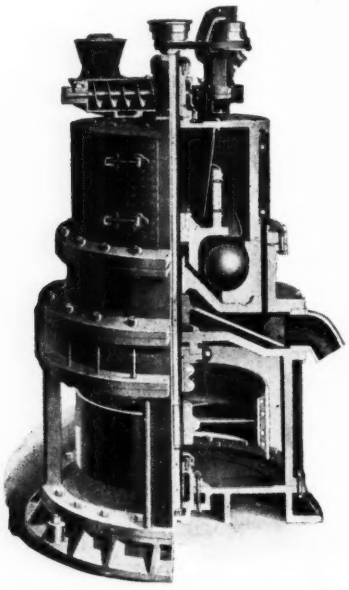
The main shaft bushings of this mill may be lubricated with either black oil or cup grease, although the intermediate bearing, because of its inaccessibility, is most conveniently lubricated with cup grease. The lower bushing and thrust bearing are arranged to operate in a bath of oil. Cylinder oil may be used successfully for this purpose, but when the gear drive and ball thrust bearing are incorporated in the machine, only oils suitable for ball bearing lubrication should be employed. The driving gears, which are used upon some types of Fuller-Lehigh mills, may be successfully operated in a bath of black oil, but because of the grit which gets into the gear case this method of lubrication is not so satisfactory as the use of a high grade gear grease. The load on the gear teeth and the dust conditions are not nearly so severe as those met with in the gyratory crusher, but the temperature in the gear case is usually quite high so about the same grade of grease should be used in both cases. The best oil



CLOSE-UP OF DRIVING AND CARRYING MECHANISM OF A KILN. NOTE THE IMMENSE GIRTH GEAR

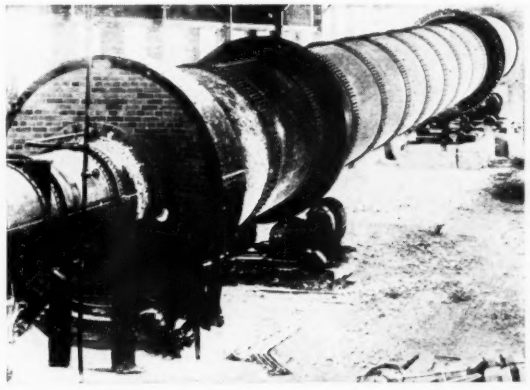
to use upon the chain-oiled bearings of the countershaft is a good grade of medium viscosity engine oil. The feeding apparatus is most successfully lubricated with a good grade of cup grease.

Rotary kilns, used for fusing the pulverized raw mixture, present one of the most difficult lubricating problems of the cement plant. With the exception that three or more riding rings are used upon some of the larger kilns and that the construction is generally heavier, the carrying, thrust and driving mechanism of the kiln is the same as that of the dryer. Their lubrication is not such a simple matter, however. The great heat generated within the kiln causes the shell to become very hot and this heat is naturally radiated to the driving and supporting machinery. The girth gears especially become so hot that oil and most greases flow from them like water.



FULLER-LEHIGH MILL SHOWING INTERIOR AND EXTERIOR CONSTRUCTION

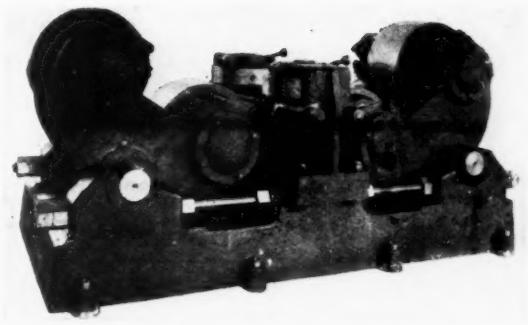
Black oil may give fairly good results on the gears of dryers but it is utterly useless on kiln gears unless applied continuously. The dust and grit aid the high temperature in drying up the lubricant and only a specially prepared grease possessing pronounced adhesiveness, a high liquefying point and considerable body will prevent metal contact and provide efficient lubrication. On one make of kiln the driving gears rotate in receptacles cast in the gear frame. These receptacles are filled with water to the level of the lowest teeth and black oil poured upon the water so that the gears continually operate in a bath of oil. Grit falling upon the teeth is at once washed



CEMENT KILN BUILT BY THE VULCAN IRON WORKS. NOTE THE LARGE QUANTITIES OF DUST

off and settles to the bottom of the receptacle. This method of lubrication is not applied to the girth gear or its pinion, however.

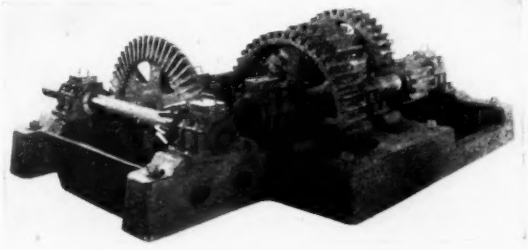
The great weight of the larger kilns combined with the radiated heat creates a lubricating problem which requires special attention. When the bearings of the rollers are water jacketed black oil or cup grease may be used with good results, but when cooling is not resorted to these often become too thin to



CARRYING AND THRUST MECHANISM OF THE VULCAN KILN SHOWN ABOVE

keep the bearing surfaces apart. In such cases the cavities in the bearings should be packed with yarn grease to which black oil should be added every two or three hours.

The fused materials issue from the kiln in the form of white hot clinkers which are either conveyed to a storage pile or cooled at once for grinding. The clinker cooler is so similar to the dryers and kilns that it needs no description here. Very little heat is radiated but the riding rings and girth gears get quite warm so a lubricant having a fairly high liquefying point should be used. It must also, of course, resist the cutting and drying action of the inevitable dust. Lubricants suitable for the dryers should prove satisfactory upon the corresponding parts of the coolers.



DRIVING MECHANISM OF THE VULCAN KILN SHOWN ABOVE

**The balance of this article, which deals with the lubrication of the machinery employed in other parts of the plant, will be presented in the July issue of LUBRICATION.**

# Why Bearings Heat

One of the most annoying and disconcerting things that can happen to an engineer, or others in charge of machinery, is an experience with a bearing on an important piece of machinery which is heating.

If a bearing on a new piece of machinery persists in heating and the operator is satisfied that the oil he is using is not too light or too heavy then the bearing may be out of line, or perhaps it has been designed with insufficient clearance. Overheating may also result when the clearance is too great and trouble may follow because the bearing has high and low spots upon its surface. A very frequent cause of bearings running hot is foreign matter which may owe its presence in the bearing to any number of causes.

Faulty oil distribution is probably the cause of overheating as frequently as anything else. The oil may be fed into the bearing at the wrong point or perhaps the grooves do not convey the oil to all parts of the bearing. Again the feed pipe may not be of sufficient size to supply the bearing with an adequate amount of oil or the oil reservoir may be too small to permit of proper cooling. We have known many cases where a hot bearing was caused through an obstruction in the oil supply pipe restricting the flow of oil.

Unsuitable bearing materials and bearings which are not large enough to carry the loads brought upon them are often the cause of heating, and all the more annoying because they do not readily suggest themselves as the root of the trouble.

The sudden heating of an erstwhile well-behaved bearing may be due to recent rebabbitting or readjustment, that is, the clearance may be set carelessly, the interior surface may be imperfectly finished or the oil grooves may be improperly cut. A reduction in the amount of oil supplied to a bearing such as that brought about by a partially plugged feed line, the lowering of the oil level in a crank case or reservoir of a ring-oiled bearing or the glazing of a lubricating pad may also cause a bearing to heat.

When the supply of oil is completely interrupted, overheating will prove especially serious and rapid. The supply of oil may be cut off through a feed pipe becoming plugged or through the oil reservoir running dry. Broken ring oilers, glazed pads, pads which have fallen away from the journal and the congealing of the oil in a system also cut off the oil supply. Dirt suddenly entering the bearing with the oil or from outside sources usually results in overheating. The more abrasive materials cause heating because they roughen the journal and bearing, but the softer materials are usually found to have plugged the oil grooves and cut off the oil supply.

If the proper oil in sufficient quantities is being fed to the bearing, overheating must be due to mechanical disarrangements. For example, a bearing may have become knocked out of line or the bearing cap may have worked loose. Overheating may result from the bearing having become badly worn due to the above causes. Excessive loads are a common cause of hot bearings. A tightened belt or a shaft which has been sprung through dirt building up between the teeth of gears might be mentioned in this connection. Excessive loads may be thrown on the main bearings of the steam engine through insufficient cushioning in the steam cylinder, and too high compression in the internal combustion engine has been known to bring about the same result.

The only way to obviate the continued heating of a bearing is to correct the underlying mechanical faults to which it is due. If sudden and unexpected heating occurs any imperfections in the lubricating system should be set right and when it is due to mechanical troubles these should be corrected at once. Do not try to "manage somehow" with a heated bearing. Many preparations and devices have been recommended for reducing the temperatures of hot bearings, but these makeshifts are as ineffective as medicines given to cure a broken leg. If a suitable oil will not keep a bearing cool, it is time to make some repairs.